STATUS OF THE FLASH II PROJECT

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Abstract

The extension of the FLASH facility at DESY (Hamburg, Germany) – FLASH II Project – is under way. The extension includes a second undulator line with variable gap undulators to allow a more flexible operation, and a new experimental hall for photon experiments. The present FLASH linac will drive the both undulator beamlines. Civil construction of the new buildings has been started in autumn 2011 continuing in several steps until spring 2013. The design of the new electron beamline including the extraction from the FLASH linac and the undulator section is mostly finished, and the manufacturing of the components is under way. Design of the photon beamline and layout of the experimental hall is in an advanced stage. The beamline mounting starts end of 2012, and the commissioning with beam is scheduled for the second half of 2013.

INTRODUCTION

FLASH [1–4], the free-electron laser (FEL) user facility at DESY, delivers high brilliance XUV and soft x-ray FEL radiation for photon experiments since summer 2005. In order to provide more beam time for user experiments and to improve the properties of the delivered FEL radiation, an extension of the FLASH facility – the FLASH II Project [5, 6] – was proposed in 2008 by DESY in collaboration with Helmholtz Zentrum Berlin (HZB). The project has been approved in 2010 and the civil construction started in 2011. The first beam of the extended facility is foreseen in late summer 2013.

LAYOUT

The present FLASH facility consists of an injector with a laser driven RF-gun to produce high quality electron bunches, a superconducting linac with TESLA type accelerator modules to accelerate the electron beam up to 1.25 GeV, and an undulator section with fixed gap undulators to produce SASE (Self Amplified Spontaneous Emission) FEL radiation. The total length of the facility including the experimental hall is about 315 meters. More details of FLASH and its parameters are, for example, in [2, 3].

The aim of the FLASH II project is to extend FLASH with a second undulator line to allow a more flexible operation and more beam time for photon experiments with improved photon beam properties. The FLASH linac drives both undulator lines: the present fixed gap undulator line (referred here as FLASH1) and the new variable gap undulator line (referred here as FLASH2). The separation between the two beamlines is downstream of the last accelerating module. Figure 1 shows the layout of the extended FLASH facility; the location of the HHG (High Harmonic Generation) seeding experiment sFLASH [7, 8] is indicated as well.

The FLASH2 undulator beamline will be placed in a new building separated from the existing FLASH tunnel. It provides enough space for future upgrades, like a third undulator line. The FLASH2 photon beamlines and experiments are located in a new experimental hall. Since most of civil construction and installation work in the new beamline building and experimental hall can take place while FLASH accelerator is in operation, the interruptions of FLASH operation could be limited to two short periods: the first one (3.5 months) has already taken place in autumn 2011, and the second one (4 months) is scheduled for spring 2013.

The extraction of the electron beam is realized by a kicker-septum system. The superconducting accelerating modules have a long RF-pulse allowing operation with up to 800 μs long electron bunch trains. The repetition rate is 10 Hz. The bunch train can be divided between the two undulator lines by using a flat-top kicker with a fast rise (or fall) time less than 50 μs. The extraction angle between FLASH1 and FLASH2 is large (12 deg). Therefore the

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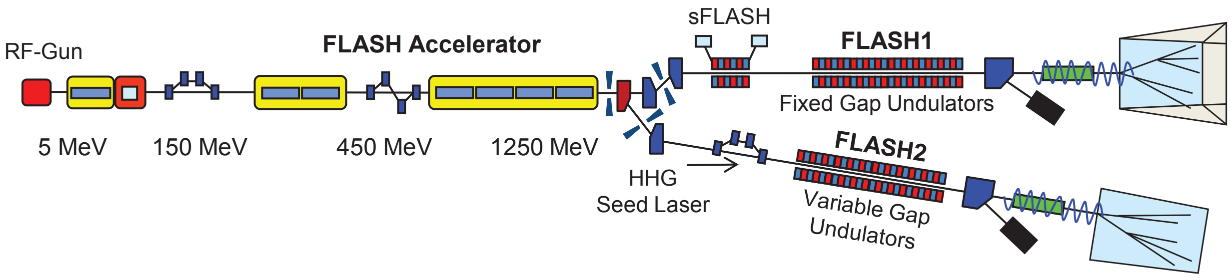

Figure 1: Layout of the extended FLASH facility with two undulator lines FLASH1 and FLASH2 (not to scale). The total length of the facility is about 315 m.

minimization of the emittance and energy spread growth due to coherent synchrotron radiation (CSR) has been carefully taken into account in the extraction arc design. More details can be found in [9].

The undulator section consists of 12 variable gap undulators. Downstream the main undulators, space is reserved for further upgrades, like a second harmonic afterburner and a THz undulator to provide radiation in the THz range for pump and probe experiments.

The photon beam is transported through a photon diagnostics section similar to [4] and, after crossing the accelerator tunnel of the PETRA III synchrotron, guided to the new experimental hall located next to the FLASH1 experimental hall. Space is available at least for five photon beamlines. In addition, experiments may be installed in a row or – in case of long photon wavelengths – at larger angles. An option of permanent photon experiment end stations is under discussion.

PARAMETERS AND CHARACTERISTICS

FLASH1 and FLASH2 are operated by the same electron linac. Therefore their main parameters – for both electron and photon beam – are similar. FLASH2 design parameters are listed in Table 1. FLASH1 parameters can be found, for example, in [2, 3].

The overall FLASH2 wavelength range is 4 - 60 nm (fundamental radiation). Since FLASH1 has fixed gap undulators, the electron beam energy is defined by the wavelength required for FLASH1 operation. Due to variable gap undulators, the FLASH2 wavelength can be tuned, to a certain extend, independently from FLASH1. Figure 2 shows examples of FLASH2 wavelength ranges for electron beam energies, which are typical for FLASH1 operation: for beam energy of 1.2 GeV, photon wavelengths between 4 and 13.5 nm are possible, for 1 GeV the available range is 6 - 20 nm, and for 700 MeV 10 - 40 nm.

In the first FLASH2 operation phase, the FEL radiation is produced using the SASE process. In addition, the seeded operation is as under preparation. The first seeding scheme to be applied is a direct HHG seeding, which is foreseen for wavelengths between 10 and 40 nm. More details can be found in [10]. Developments on advanced

Table 1: FLASH2 Design Parameters

Electron beam		
Energy	GeV	0.5 - 1.25
Peak current	kA	2.5
Emittance, norm. (x,y)	μm rad	1 - 2
Bunch charge	nC	0.02 - 1
Energy spread	MeV	0.5
Bunch spacing	μs	1 - 25
Rep. rate	Hz	10
Undulator		
Period	mm	31.4
Segment length	m	2.5
Number of segements		12
Photon beam SASE		
Wavelength (fundamental)	nm	4 - 60
Average single pulse energy	μJ	1 - 500
Pulse duration (fwhm)	fs	10 - 500
Spectral width (fwhm)	%	0.5 - 2
Peak power	GW	1 - 5
Peak brilliance	*	10^{28} - 10^{31}
Photon beam HHG		
Wavelength (fundamental)	nm	10 - 40
Average single pulse energy	μJ	1 - 50
Pulse duration (fwhm)	fs	10 - 50
Spectral width	%	Fourier limited
Peak power	GW	1 - 5
Peak brilliance	*	10^{28} - 10^{31}

* photons / (s mrad^2 mm^2 0.1 % bw)

HHG sources and on a laser system appropriate for the HHG seeding are under way [11]. The recent experimental demonstration of the direct HHG seeding at 38 nm by sFLASH [8] is also an important step for the FLASH II project.

Seeding schemes for short wavelengths (below 10 nm) are under discussion. One candidate is a cascade HGHG (High Gain Harmonic Generation) [12]. Considerations of an EEHG (Echo-Enabled Harmonic Generation) seeding have also been carried out [13].

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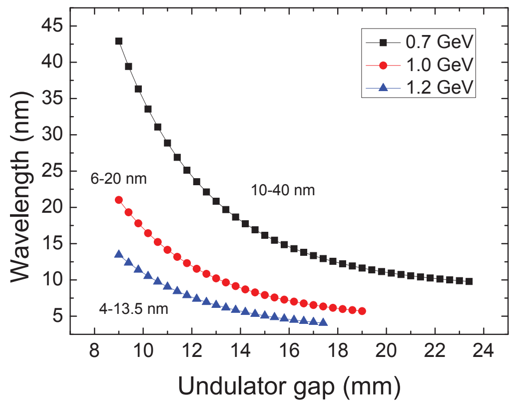

Figure 2: FLASH2 photon wavelength as a function of the undulator gap for three electron beam energies [6].

OPERATIONAL ISSUES

Every photon experiment has its own demands on the beam parameters like photon wavelength, pulse duration, number of pulses, and pulse spacing. The ultimate goal is to operate FLASH1 and FLASH2 simultaneously for different kind of experiments. However, since one accelerator drives both beamlines, the beam parameters delivered for FLASH1 and FLASH2 users can not be completely independent from each other.

Since FLASH1 has fixed gap undulators, the electron beam energy is defined by the wavelength required by the FLASH1 experiment. The FLASH2 wavelength can be adjusted by changing the undulator gap. The experiments must, however, be organized such that their requested wavelength can be obtained with the same electron beam energy. A small change of the electron beam energy – in other words of the photon wavelength – of only one of the beamlines can be realized by applying a slightly different accelerating gradients for the first and the second part of the 800 μs long RF-pulse flat-top.

In the case of a simultaneous operation, every RF-pulse is shared between two bunch trains: the train transported to FLASH1 and the train deflected by the kicker-septum system to FLASH2. Both beamlines are served with the same 10 Hz repetition rate. Different bunch patterns (number of bunches, bunch spacing, bunch charge) in the two bunch trains can be realized by using two separate injector laser systems. Development of a laser pulse kicker system [14] allowing a bunch pattern manipulation is in progress as well.

Operation with different electron bunch charges allow different photon pulse durations for the FLASH1 and FLASH2 experiments.The practicable charge difference is, however, limited by the electron beam dynamics and acceptance of the beam optics.

More detailed discussion of the simultaneous operation, including results from performance tests, is in [15].

STATUS AND OUTLOOK

The civil construction started in autumn 2011. The first step was the construction near the existing FLASH tunnel. In order to carry out this part of the work, the radiation shielding of the FLASH tunnel had to be removed. Therefore, a 3.5 months shutdown was scheduled from mid September to the end of 2011. The second step has been the civil construction near the PETRA III tunnel taking place early 2012 during the regular PETRA III winter shutdown. The remaining building construction does not require any further interruptions of FLASH or PETRA III beam operation. The beamline building is presently under construction and is scheduled to be completed by the end of this year. The construction of the experimental hall takes place from autumn 2012 to spring 2013. Figure 3 shows the FLASH2 construction site in August 2012.

Figure 3: FLASH2 construction site August 2012.

The design of the FLASH2 main beamline has been finished in spring 2012, and most its components are already manufactured. The design of the extraction beamline, including modifications required for FLASH beamline between the last accelerating module and the septum, is finalized end of August 2012. The design of the HHG beamline is on-going, as well as the design of the photon diagnostics and photon beamlines.

The mounting of the FLASH2 main beamline starts in winter 2012/13, and the undulators will be installed in spring 2013. The connection of FLASH2 to the FLASH linac, including the mounting of the extraction arc, requires interruption of FLASH beam operation. A four months shutdown starting mid February 2013 is scheduled for this work. The installation of the basic photon diagnostics is scheduled for summer 2013, and the first photon beamline in the experimental hall is expected to be available early 2014.

The technical commissioning of components and subsystems starts in spring 2013. The first electron beam through FLASH2 is foreseen late summer 2013. As soon as the kicker-septum system has been commissioned, most of

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the FLASH2 beam commissioning can take place parasitic to the FLASH1 user operation. In addition, periods dedicated explicitly to FLASH2 operation will be scheduled in a regular basis. As mentioned above, FLASH2 will start with the SASE mode; the installation of the HHG hardware is planned for autumn 2014.

A goal is to demonstrate a stable simultaneous operation of FLASH1 and FLASH2 by early 2014. The first FLASH2 pilot photon experiments are expected mid 2014.

SUMMARY

Extension of the FLASH facility with a second undulator beamline is under way. The civil construction is on-going, and the beamline mounting will start soon. The first beam in FLASH2 is expected in late summer 2013.

ACKNOWLEDGMENT

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